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ASYMMETRIC ALTERNATING PRISM ARRAYS

RELATED APPLICATIONS

This application claims the benefit of U.S. Application No. 60/208,339, filed May 31, 2000, and U.S. Application No. 60/168,586, filed on December 2, 1999, the
5 entire teachings of the above applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Luminaires typically include a lighting source, a waveguide, and microprisms used to redirect the light in a desired direction. These luminaires are used to provide a more uniform light distribution than conventional light systems and alleviate glare in
10 applications such as office space, boardrooms, and customer service centers.

SUMMARY OF THE INVENTION

A luminaire is provided which includes a light source, a light guide that receives light radiating from the light source, and a plurality of tilted prism arrays for redirecting the light in a first direction. In one embodiment, the plurality of prism arrays, which can
15 include linear prisms, periodically alternate orientation along the light guide. The linear prisms can have included angles of 25, 90, and 65 degrees. The prism arrays can alternate or flip-flop in orientation every few millimeters, for example, one to two millimeters. A tilted prism can have sides on each side of the peak with a first length from the valley to the peak on one side and a second length from the valley to the peak

on a second side of the prism, where the first length is different in length from the second length, thereby tilting or canting the prisms. The tilting angle of the prisms is between the optical axis and a line perpendicular to the window side. The tilting angle can be in the range between about 20 and 70 degrees.

- 5 The prism arrays can include peaks and valleys along a first axis. The prism arrays can also include peaks and valleys along a second axis different than the first axis, such as substantially perpendicular or offset about 60 degrees relative to the first axis. The prism arrays can further include peaks and valleys along a third axis that is different than the second axis and the first axis. In one embodiment, the third axis is
- 10 offset about 60 degrees relative to the second axis. The plurality of prism arrays can be disposed on a top surface of the light guide.

- An optical microstructure is also provided which includes a plurality of tilted prism arrays that periodically alternate orientation of the tilted prism arrays along a first axis. The prism arrays can also periodically alternate orientation along a second axis
- 15 and, in alternative embodiments, along a third axis. The optical microstructure can be disposed on a first surface of a film. A plurality of prism arrays can be disposed on a second surface of the film. The plurality of prism arrays on the second surface can be tilted and periodically alternate orientation along at least one axis. The purpose of the periodic alternate orientation of the prism angles is to create alternating bands of bright
- 20 and dark lines which can be seen viewing the surface of the luminaire. Very small or fine pitch prisms that are not visible to the human eye beyond 0.5 meters can be made to look like macro prisms because of the visibility of the bright and dark bands. Low cost manufacturing concepts, such as continuous casting, can be used to form the precision fine pitch alternating prism groups and achieve the appearance of a precision macro
- 25 prism, for example, 0.508 to 2.54 mm (0.02 to 0.1 inch) pitch, which would normally be made with a more expensive manufacturing concept, such as compression molding.

Multi-faceted prisms can be used, for example, prisms that have more than one slope on a facet. Further, prisms can be used which have curved facets or curved prism tips and valleys. These features are used to smooth the resulting light distribution.

A method for redirecting light is also provided which includes providing a light source, receiving light radiating from the light source in a light guide, and redirecting the light in a first direction with a plurality of tilted prism arrays that periodically alternate orientation along a first axis. The plurality of tilted prism arrays can
5 periodically alternate orientation along a second axis different than the first axis. The plurality of tilted prism arrays can further periodically alternate orientation along a third axis which is different than the second axis.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other objects, features and advantages of the invention will be
10 apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention.

15 Figure 1 is a partial cross-sectional view of a waveguide for use in a display apparatus particularly illustrating linear prisms arranged in accordance with the present invention.

Figure 2 is a cross-sectional view of a luminaire employing waveguide of Figure 1.

20 Figure 3 is a cross-sectional view of a pair of waveguides which receive and direct light from a light source substantially downward.

Figure 4 is a graph illustrating light output of an exemplary backlit display apparatus at an observation or viewing angle range of about -90° to $+90^{\circ}$.

25 Figure 5 are graphs illustrating light output of an exemplary backlit display apparatus at viewing range of about -70° to $+70^{\circ}$.

Figure 6 is a cross-sectional view of an alternative embodiment of a luminaire in accordance with the present invention.

Figure 7 illustrates photometric data from the luminaire of Figure 6.

Figure 8 is a cross-sectional view of another embodiment of a luminaire in accordance with the present invention.

Figure 9 is a cross-sectional view of yet another embodiment of a luminaire in accordance with the present invention.

5 Figure 10 is a cross-sectional view taken along line 10-10 of Figure 6.

Figure 11 is an enlarged view of the prisms shown in Figure 6.

DETAILED DESCRIPTION OF THE INVENTION

A description of preferred embodiments of the invention follows. Generally, the invention is directed to a backlit display apparatus ("BLDA") having a coarse
10 appearance. An example of a BLDA is disclosed in U.S. Patent 5,629,784, issued to Abileah *et al.* on May 13, 1997, the teachings of which are incorporated herein in its entirety by reference.

Figure 1 is a partial cross-sectional view of a waveguide or light guide 10 for use in a BLDA particularly illustrating the linear prisms 12. The prism angles, in one
15 embodiment, are 25°-90°-65° (90° is the peak angle with a first side of the prism is 25° from the horizontal to peak and a second side of the prism is 65° from the horizontal to the peak). The pitch, or tip to tip spacing, in one embodiment, is in the range from about 0.0508 to 0.254 mm (0.002 to 0.01 inches). The tilting angle, as measured from the peak angle, can be in the range between about 20 and 70 degrees. The prism arrays
20 preferably alternate or flip-flop in orientation, i.e., they are mirror images with respect to line L. In one embodiment, the prism arrays flip-flop every few millimeters, for example, one to two millimeters.

The waveguide 10 can be solid being formed from a material such as polymethyl methacrylate (PMMA) or other suitable materials. In alternative embodiments, any of
25 the prisms disclosed herein can be used with hollow waveguides in any of the embodiments as disclosed in U.S. Application No. _____, Attorney's Docket No. 1571.1140-001, filed on even date herewith, the contents of which are incorporated herein by reference.

When viewed from below, one set of fine pitch prisms 12 is generally oriented to reflect light towards the viewer, and the neighboring pair away from the viewer. Thus, the viewer sees a set of alternating bright and dark lines, which can be referred to as a coarse appearance. It is understood that the number of prisms 12 within a prism

5 grouping is variable, which means that the width of a group and its coarseness can be easily controlled.

Figure 2 illustrates a luminaire 8 having an exemplary waveguide 10 coupled to a light source 14, such as a fluorescent cylindrical bulb. A viewer at point X sees the center group of prisms 12 as brighter because they direct light from the source 14 to

10 point X. Since the light from adjacent prism groups is directed elsewhere, these groups appear dark. At point Y, the center group can appear dark, and the adjacent groups are brighter. At some point between X and Y, the groups appear to be equal in brightness. Further, the output light distribution is such that the image of the light source 14, such as a cylindrical bulb, is masked. It is noted that the prisms 12 of Figure 2 are

15 substantially enlarged for illustrative purposes only.

Figure 3 illustrates a luminaire 9 having a pair of waveguides 10 which receive and direct light from source 14 substantially downward. A reflective coating 16, such as vacuum metalized aluminum or metalized polyester (PET) or polished aluminum, is provided on the top and end surfaces of the waveguide 10 to allow the light rays to be

20 directed substantially downward.

Figure 4 is a graph illustrating light output (luminance: y axis) of an exemplary BLDA at an observation or viewing angle range of about -90° to $+90^{\circ}$ (x axis). The coarseness or banding appears in this embodiment from approximately -45° to $+45^{\circ}$. In this embodiment, the pitch, or tip to tip spacing, is in the range from about 0.0508 to

25 0.254 mm (0.002 to 0.01 inches).

Figure 5 are graphs illustrating light output (lux: y axis) of an exemplary BLDA at viewing angle range of about -70° to $+70^{\circ}$ from normal (x axis). One graph illustrates the light output across the light source or bulb while the second graph illustrates the light output with the bulb. The data for the graphs are shown in Figure 5.

Figure 6 illustrates an alternative embodiment of a luminaire 11 having an exemplary waveguide 10' and prisms 12' wherein the waveguide and prisms are formed separately and laminated together, for example, with a pressure sensitive adhesive (PSA). The waveguide 10' and prisms 12' can be formed from different materials. In one embodiment, the prisms 12' can be formed from an ultraviolet (UV) curable acrylate thermoset or other suitable materials. Either the waveguide 10' or the prisms 12' (or both) can be colored and/or have printed patterns formed thereon (e.g., logos) to customize the appearance of the luminaire as disclosed in U.S. Application Nos. 09/013,696, now U.S. Patent No. 6,119,751, and 09/170,014, now U.S. Patent No. 6,120,636, filed January 26, 1998 and October 13, 1998, respectively, the teachings of each being incorporated herein in their entirety by reference.

Figure 7 illustrates photometric data from a light system, such as shown in Figure 6. The photodetector was placed about 1.0 meter from the light source. The data represents theoretical and actual measurements taken across the bulb direction, i.e., in the direction of the two-headed arrow 18 of Figure 6.

Figure 8 illustrates another embodiment of a luminaire 19 having mirrors 20 positioned on the ends of the waveguide 10 and above and below the light source 14. The prisms 12' can be integral to the waveguide 10, or alternatively, be laminated to the waveguide 10.

Figure 9 illustrates a luminaire 22 which is similar to the embodiment of Figure 8 but instead of a mirror above the light source 14, a baffle 24 is provided there instead. The baffle 24 can include a white surface which absorbs, diffracts, and scatters light from the light source 14. It is believed that this baffle 24 more uniformly directs the light rays into the waveguide 10 for achieving a more uniform distribution of the light rays in the waveguide.

The table below compares the viewing angle, the measured luminance for the luminaire 19 of Figure 8 and theoretical output for a luminaire having a baffle such as the luminaire 22 of Figure 9. In this embodiment, the pitch of the prisms is about 0.254 mm (0.01 inches).

	Angle	Measured Luminance (cd/lux/m ²)	Theoretical with Baffle
5	180	5.7	16.8458
	185	5.1	18.9760
	190	5.1	15.2260
	195	5.3	8.9539
	200	7.6	15.5152
10	205	13.8	27.0215
	210	19.9	37.7291
	215	28.2	33.6113
	220	37.0	37.6789
	225	44.7	44.4249
15	230	48.9	40.6028
	235	47.4	41.2673
	240	39.3	35.1872
	245	26.1	24.0277
	250	10.9	10.6000
20	255	4.9	4.7000
	260	4.6	4.5000
	265	4.3	4.2000
	270	1.7	1.6000
	275	2.8	2.7000
25	280	5.5	5.4000
	285	9.5	8.8104
	290	13.0	10.9029

5	295	15.5	5.3704
	300	17.0	8.9190
	305	18.7	5.3252
	310	21.7	13.4086
	315	26.2	18.7654
10	320	31.8	22.4112
	355	38.3	32.3889
	330	45.6	43.3254
	335	54.5	45.7689
	340	53.0	56.6042
15	345	45.1	49.3210
	350	33.0	45.7512
	355	21.8	47.1792
	0	17.4	41.8723
	5	20.2	54.5000
20	10	30.4	48.0831
	15	41.6	46.7072
	20	49.6	45.5090
	25	51.36	47.0374
	30	44.0	38.3052
25	35	36.0	32.6696
	40	29.2	21.6011
	45	23.8	19.2380
	50	19.2	11.7001
	55	15.7	6.5985
	60	13.4	4.6328

5	65	12.0	7.7141
	70	10.0	9.9115
	75	7.5	7.4000
	80	7.4	7.3000
	85	3.1	3.0000
10	90	1.9	1.8000
	95	3.4	3.3000
	100	3.7	3.6000
	105	4.0	3.9000
	110	7.2	7.1000
15	115	21.5	21.4000
	120	37.2	35.3846
	125	46.5	42.8789
	130	49.7	45.9643
	135	46.7	45.6916
20	140	38.6	38.2638
	145	29.6	36.6630
	150	21.1	33.6147
	155	14.3	32.8648
	160	8.2	13.3652
	165	5.5	10.2196
	170	5.1	15.5559
	175	5.3	18.9760

The linear prisms 12 as described above can be referred to as a one-dimensional structure. That is, the prism structures 12 have peaks and valleys running along one

axis. In alternative embodiments, the prisms 12 can include multiple-dimensional structures, such as two-dimensional structures and three-dimensional structures.

For example, in the embodiment of Figure 6, a two-dimensional prism structure can be constructed by forming a second array of linear prisms perpendicular to the linear prisms 12'. More particularly, a row of linear prisms having peaks 26 and valleys 28 is formed perpendicular to the longitudinal axis of the existing linear prisms 12', i.e., into the paper. Thus, a cross-sectional view taken along line 10-10 is seen in Figure 10. If the prisms are spaced apart, the peaks 26 will have a flat portion as also illustrated in Figure 10. Figure 11 illustrates an enlarged view of the prisms of Figure 6 which illustrates peaks 26 and valleys 28 of the prism arrays. This facilitates controlling of the light rays exiting the waveguide at every angle. In alternative embodiments, the peaks and valleys can be offset at about 60 degree intervals to provide a three-dimensional structure. In further embodiments, the peaks and valleys can be offset at various angles to provide a multiple-dimensional structure.

In alternative embodiments, optical microstructures can be formed on, laminated to, or otherwise provided on sheets, panels, or films for use in luminaires in which control of light distribution is desired. Furthermore, each side of the sheet, panel, or film can have an optical microstructure thereon. These optical microstructures can have tilted prism arrays which alternate orientation along one or more axes.

In any of the disclosed embodiments, multi-faceted prisms can be used, for example, prisms that have more than one slope on a facet. Further, prisms can be used which have curved facets or curved prisms tips and valleys. These features can be used to smooth the resulting light distribution.

While this invention has been particularly shown and described with references to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.